DISTRIBUTION AND ABUNDANCE OF THE KITTLITZ'S MURRELET *BRACHYRAMPHUS BREVIROSTRIS* IN SELECTED AREAS OF SOUTHEASTERN ALASKA

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SUMMARY

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We conducted boat-based surveys for the Kittlitz's Murrelet *Brachyramphus brevirostris* during the breeding season in southeastern Alaska from 2002 to 2009. We completed a single survey in seven areas and multiple annual surveys in three areas. Although surveys spanned a broad geographic area, from LeConte Bay in the south to the Lost Coast in the north (~655 km linear distance), roughly 79% of the regional population of Kittlitz's Murrelet was found in and between Icy and Yakutat bays (~95 km linear distance). The congeneric Marbled Murrelet *B. marmoratus* outnumbered the Kittlitz's Murrelet in all areas surveyed except Icy Bay; in fact, Kittlitz's Murrelet abundance constituted a relatively small proportion (7%) of the total *Brachyramphus* murrelet abundance in our survey areas. In areas for which there are multiple years of survey data, Kittlitz's Murrelet abundance varied considerably, whereas Marbled Murrelet abundance was comparatively stable during the same time period. Since the southern distribution of this species has likely narrowed over the last 50 years, and the distribution of the Kittlitz's Murrelet appears to be restricted to glacially influenced marine waters in southeastern Alaska, we expect that any future changes in glacial extent will likely affect this species and its long-term persistence in the region.

Key words: Kittlitz's Murrelet, *Brachyramphus brevirostris*, southeast Alaska, density, abundance, at-sea surveys

INTRODUCTION

The Kittlitz's Murrelet *Brachyramphus brevirostris* is a rare alcid endemic to coastal Alaska and the Russian Far East. In the breeding season (May–August), the greatest concentrations of Kittlitz's Murrelet are often found at sea, in glacial fjords and bays, and in the outflows of glacial streams and rivers (Day *et al.* 1999). Although this association is poorly understood, the recent and rapid retreat of Alaska's glaciers (Arendt *et al.* 2002, Molnia 2008) raises concern for the fate of this species (Kuletz *et al.* 2003), which is currently a candidate for listing under the US *Endangered Species Act* (US Fish and Wildlife Service 2010).

Southeastern Alaska contains the largest system of temperate icefields in North America and nearly half of Alaska's tidewater glaciers (Molnia 2008). Although glacial fjords are thought to represent typical habitat for the Kittlitz's Murrelet (Day *et al.* 1999), there is little information on the distribution and abundance of this species in this region, with the exception of Glacier Bay (Robards *et al.* 2003, Lindell 2005, Drew *et al.* 2007). For example, museum specimens are sparse for southeastern Alaska, with the majority taken in a single location (Glacier Bay); only a few additional areas are represented (Icy Strait, LeConte Bay, coastal Gulf of Alaska, Yakutat Bay, Icy Bay, Holkam Bay, Sitka Sound and Port Houghton; R. Day, ABR, Inc., Fairbanks, Alaska, unpublished data). In the early 1990s, several boat-based surveys were done in southeastern Alaska with the primary goal of estimating abundance of the more common Marbled Murrelet *B. marmoratus* (Kozie 1993, Agler *et al.* 1998, Stephensen & Andres 2001, Lindell 2005). Although these surveys documented relatively large numbers of Kittlitz's Murrelets along the Malaspina Forelands, Yakutat Bay and Glacier Bay (Fig. 1), the resulting population estimates for Kittlitz's Murrelet were imprecise, mainly because of the species' general rarity and patchy distribution (Kozie 1993, Kendall & Agler 1998, Stephensen & Andres 2001). Additionally, large sections of presumably suitable habitat for Kittlitz's Murrelet in southeastern Alaska remained unsurveyed.

We conducted boat-based surveys for Kittlitz's Murrelet in southeastern Alaska during the breeding season from 2002 to 2009. Our surveys were intended to (1) complement those of Agler *et al.* (1998) for *Brachyramphus* murrelets by completing survey coverage of southeastern Alaska, and (2) increase the precision of abundance estimates in areas where Kittlitz's Murrelet was known or suspected to be found. We selected areas to survey based on previous survey data, anecdotal observations and suitability of habitat, with one exception: we did not survey Glacier Bay because that area already had an active population monitoring program for marine birds (Piatt *et al.* 2011). In this paper, we compile the results of our standalone surveys and analyze our survey data in a manner consistent with previous efforts (Kozie 1993, Stephensen & Andres 2001) to maximize comparability. We aim to summarize the current distribution and abundance of Kittlitz's Murrelet in southeastern Alaska (outside of Glacier Bay); for comparison, we also present abundance estimates for the Marbled Murrelet in our study areas.

STUDY AREA AND METHODS

Southeastern Alaska is defined as the region east of 144°W longitude, consisting of the large group of islands called the Alexander Archipelago and a strip of mainland that stretches from Cape Suckling in the north to Dixon Entrance in the south (Fig. 1). The region is roughly 900 km long, averages 230 km in width, and is characterized by rugged topography, coastal fjords and more than 2000 islands.

We conducted one survey of seven previously unsurveyed areas. These included, from south to north (survey year in parentheses), LeConte Bay (2002), Thomas Bay (2002), Wilderness Bays (Holkam Bay and Tracy and Endicott arms; 2002), Cross Sound (2003), Outer Coast (including four subareas; 2003, 2004), Manby Point (2002), and Lost Coast (from Icy Cape to Duktoth River; 2008; Fig. 1). We also resurveyed three areas: Yakutat Bay (2009; Stephensen & Andres 2001), Malaspina Forelands (2002, 2008, 2009; Kozie 1993), and Icy Bay (2002, 2005, 2007–2009).

We used three sampling designs to estimate the abundance of *Brachyramphus* murrelets. The choice of design depended on logistics, safety and consistency with previous surveys (Table 1). In most areas, we counted birds from a boat (6 m long and ~3 m high) travelling at a speed of ~10 km/h following linear transects perpendicular to the shore. Transects were spaced roughly 2 km apart (except in Yakutat Bay) and approached as close to shore as possible (<200 m; Fig. 2). In Yakutat Bay, we repeated linear transects established by Stephensen & Andres (2001) that were 7 km apart; we then added transects at a spacing of 3.5 km to improve spatial coverage. We also conducted shoreline surveys (i.e. surveys conducted within 200 m of mean high tide) but they are not included in this analysis. In areas with few safe anchorages, we followed zigzag transects using a 22 m vessel (~6 m high) at a speed of 10–15 km/h. Survey boundaries were delineated using the 18.3 m (10 fathom) depth line (approximately 1 km offshore) and a 5.5 km (3 nautical mile) line offshore, with endpoints spaced 5 km apart to create a zigzag pattern (Fig. 2). We chose those boundaries because they are often delineated on nautical charts, provided an acceptable depth for the large vessel to navigate safely, and allowed for sufficient fuel between available refueling stations. We repeated one linear transect (Malaspina Forelands) parallel to shore, roughly 82 km in length and 1 km from shore, initially surveyed by Kozie (1993).

We surveyed between 0700 and 2100 h from 3–23 July in all years, except the surveys in Yakutat Bay, which we surveyed from 17 to 22 June for comparison with Stephensen & Andres (2001; Table 2). We selected the July dates to coincide with the peak timing of after-hatch-year murrelets in our study area (Kissling *et al.* 2007) or to be consistent with previous surveys. In all areas except Icy Bay, we conducted one survey per year; in Icy Bay, we completed one to three replicate surveys per year (Table 1). We used line-transect survey methods (Buckland *et al.* 2001) in all years except 2002 when we used strip transects with a 200 m strip width. We accounted for detection probability in all strip-transect surveys (including reanalysis of Kozie [1993] and Stephensen & Andres [2001]) using data from line-transect surveys (see Data analysis; Table 1). We tested and complied with the assumption of perfect detection on the line for line-transect surveys (Lukacs *et al.* 2010). In most years, we recorded all bird and mammal species observed, but in 2005 and 2007 in Icy Bay we recorded only *Brachyramphus* murrelets because the data were used as part of a separate study (Kissling *et al.* 2007). We considered results from surveys of multiple species and of *Brachyramphus* murrelets only to be comparable because we found that the probability P of detecting *Brachyramphus* murrelets was similar in murrelet-only surveys (2005: 0.44, SE 0.02; 2007: 0.62, SE 0.03) and in multi-species surveys (2008: 0.55, SE 0.02; 2009: 0.45, SE 0.04).

For each observation, we noted group size (birds within 2 m of one another at first detection or birds more than 2 m apart but exhibiting associative behavior; Raphael *et al.* 2007), behavior (on

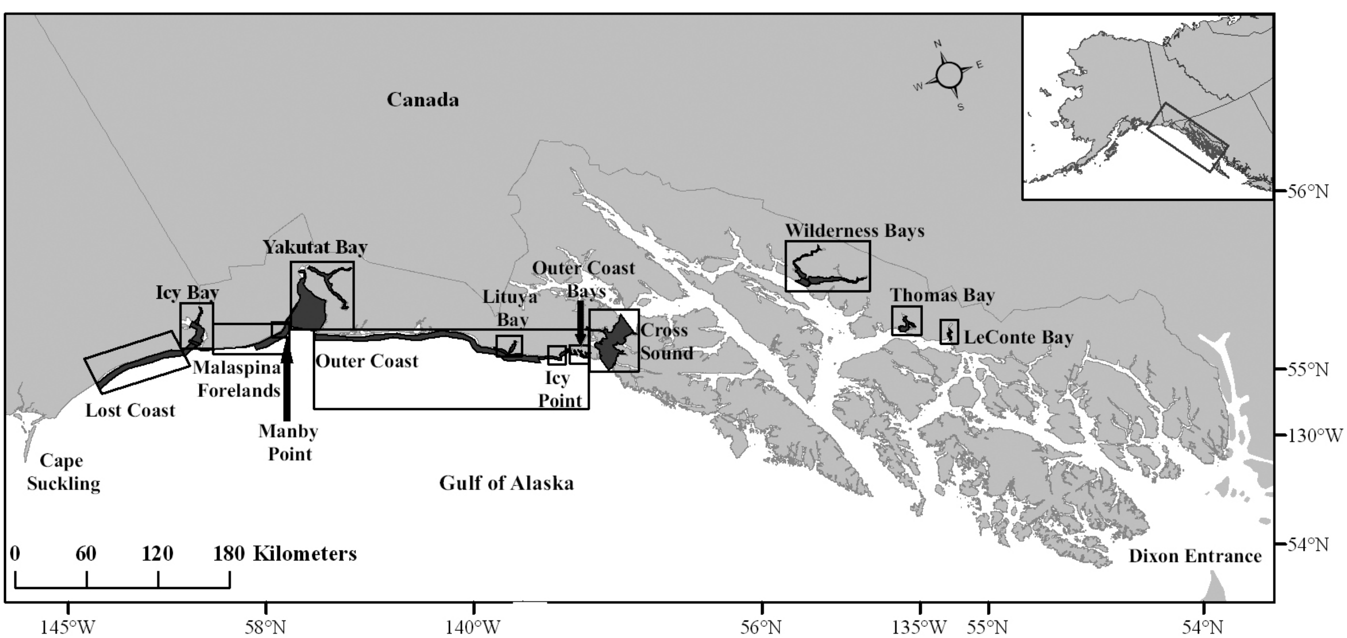

Fig. 1. Map of survey areas and subareas (dark gray) sampled for Kittlitz's Murrelet in southeastern Alaska, 2002–2009.

water, flying), and estimated distance in 25 m bins (2003 and 2004) or estimated actual distance from the trackline (2005, 2007–2009) when the bird or group was first sighted. Every 30 min we recorded weather and sea conditions (Beaufort scale), ice cover (%), swell height and depth (m). We did not conduct surveys if weather conditions were unacceptable (Beaufort scale > 2). We recorded data using a voice-activated recording system integrated with a GPS unit that stamped each observation with a location and time (Fischer & Larned 2004). Observers were trained in bird identification and distance estimation before conducting surveys, and observers were rotated every 2–3 hours during surveys to stay alert and focused.

Data analysis

We used programs DISTANCE (Thomas *et al.* 2009) and R (R Development Core Team 2009) to estimate density, abundance and associated variances for Kittlitz's and Marbled murrelets. We considered transects as sampling units for computing encounter rate variance in each area or subarea and estimated abundance using distance sampling methods (Buckland *et al.* 2001). We estimated detection functions for both *Brachyramphus* species, assuming their detection patterns were similar. To account for detection probabilities in strip-transect surveys (1992, 2000, 2002), we applied the estimated detection function from the line-transect surveys in each area or in the most similar area (Table 1). For areas with replicate surveys in a given year, we report the survey with peak abundance of *Brachyramphus* murrelets to lessen the effects of weather, phenology, or other environmental or biological factors that we did not measure.

We fit distance data to three detection functions and combinations of adjustment terms: half-normal with Hermite polynomials, hazard-rate with simple polynomials, and uniform with cosine terms. We selected the best model to estimate detection probability based on minimum Akaike's Information Criterion and model fit (Burnham & Anderson 2002). Following Raphael *et al.* (2007), we

TABLE 1

Description of survey areas, sampling effort and design to estimate abundance of Kittlitz's Murrelet in southeastern Alaska, 2002–2009. Included are summary statistics for replicate surveys with peak abundance of *Brachyramphus* murrelets

Area or subarea	Year	Survey platform	No. of replicate surveys	Total area (km^2)	Transect layout	Transect type	No. of transects	Total transect length (km)
LeConte Bay	2002	6 m boat	1	14	perpendicular to shore	strip[a]	4	6
Thomas Bay	2002	6 m boat	1	59	perpendicular to shore	strip[a]	8	21
Wilderness Bays	2002	6 m boat	1	237	perpendicular to shore	strip[a]	22	58
Cross Sound	2003	6 m boat	1	604	perpendicular to shore	line	15	157
Outer Coast	2004	22 m vessel	1	809	zigzag	line	61	404
Outer Coast Bays	2003	6 m boat	1	32	perpendicular to shore	line	11	16
Icy Point	2003	6 m boat	1	45	perpendicular to shore	line	13	26
Mouth of Lituya Bay	2004	6 m boat	1	32	perpendicular to shore	line	10	17
Lituya Bay	2003	6 m boat	1	23	perpendicular to shore	line	7	15
Yakutat Bay	2000	7 m boat	1	1132	perpendicular to shore	strip[b]	27	160
	2009	6 m boat	1	1132	perpendicular to shore	line	33	223
Manby Point	2002	22 m vessel	1	171	zigzag	strip[c]	8	50
Malaspina Forelands	1992	4 m boat	2	16	parallel to shore	strip[c,d]	1	82
	2002	22 m vessel	1	16	parallel to shore	strip[c]	1	82
	2008	22 m vessel	1	16	parallel to shore	line	1	82
	2009	22 m vessel	1	16	parallel to shore	line	1	82
Icy Bay	2002	6 m boat	1	96	perpendicular to shore	strip[a]	9	54
	2005[e]	6 m boat	3	135	perpendicular to shore	line	15	70
	2007[e]	6 m boat	3	104	perpendicular to shore	line	12	54
	2008	6 m boat	2	113	perpendicular to shore	line	17	56
	2009	6 m boat	1	135	perpendicular to shore	line	9	70
Lost Coast	2008	22 m vessel	1	439	zigzag	line	9	98

[a] Applied average detection probability estimated from Icy Bay, 2005–2009.
[b] Applied detection probability from Yakutat Bay, 2009; surveys conducted by Stephensen & Andres (2001).
[c] Applied average detection probability from Malaspina Forelands, 2008–2009.
[d] Surveys conducted by Kozie (1993).
[e] Only *Brachyramphus* murrelets recorded.

included flying murrelets in our analyses. There was a relatively small proportion of flying birds in our dataset (Kittlitz's = 13%, Marbled = 11%, unidentified = 38%) and ~20% of those were truncated during analysis because they were estimated to be beyond 150 m of either side of the boat. We estimated the proportion of *Brachyramphus* murrelets not identified to species (hereafter, unidentified murrelets) that were Kittlitz's and Marbled murrelets using the proportions of identified murrelets within 100 m or 150 m of the boat, depending on the size of the vessel (except in the Malaspina Forelands, where we used the proportion of birds within 100 m to be consistent with Kozie [1993]). Rates of probability of detection and identification were greatest within those zones (Table 2). We incorporated the variance of the unidentified murrelet estimate into the overall variance of the Kittlitz's and Marbled murrelet estimates using the delta method (Williams *et al.* 2002).

RESULTS

We observed Kittlitz's Murrelets in Wilderness Bays in the south to Lost Coast in the north, but not in LeConte Bay or Thomas Bay (Table 2). We identified only two Kittlitz's Murrelets near the entrance to Cross Sound (604 km^2 in area) in ~157 km of transects surveyed (Tables 1, 2). We identified Kittlitz's Murrelets in Lituya, Yakutat and Icy bays, and all sheltered bays adjacent to the Gulf of Alaska, but the species was distributed irregularly in the Outer Coast, Malaspina Forelands, Manby Point and Lost Coast (Fig. 3a). We observed Marbled Murrelets in all survey areas except LeConte Bay (Table 2); however, in contrast to the Kittlitz's Murrelet, the Marbled Murrelet was well-distributed throughout all areas in where it was found, including Cross Sound and portions of the Gulf of Alaska (e.g. Outer Coast, Malaspina Forelands and Lost Coast), with the exception of Icy Bay where it was restricted to the entrance to the bay (Fig. 3b).

The largest populations and highest densities of Kittlitz's Murrelet were found in and between Yakutat and Icy bays, where roughly 79% of the regional population was estimated to reside (39% of the total area sampled; Tables 1, 2). Smaller populations (<1000 birds) of Kittlitz's Murrelet were found in the Lost and Outer coast survey areas (Fig. 3a), which constituted 37% of the total area sampled but only 13% of murrelets (Tables 1, 2). In contrast, the Marbled Murrelet was more abundant in the same areas, particularly Cross Sound (Table 2, Fig. 3b), outnumbering Kittlitz's Murrelet everywhere except Icy Bay (where the proportion was 82% Kittlitz's, 14% Marbled murrelets, and 4% unidentified murrelets; Table 2). The subareas near Lituya Bay and Icy Point contained relatively high densities of Kittlitz's Murrelet compared with the remainder of the Outer Coast, but the size of those areas was so small (<45 km^2) that they contributed little (3%) to regional abundance (Table 2; Fig. 3a). The southernmost population of Kittlitz's Murrelet numbered 555 (SE 233) birds in Wilderness Bays (Fig. 4), but only 27 birds were observed on 18% (4 of 22) of the transects, resulting in an imprecise abundance estimate (Table 2).

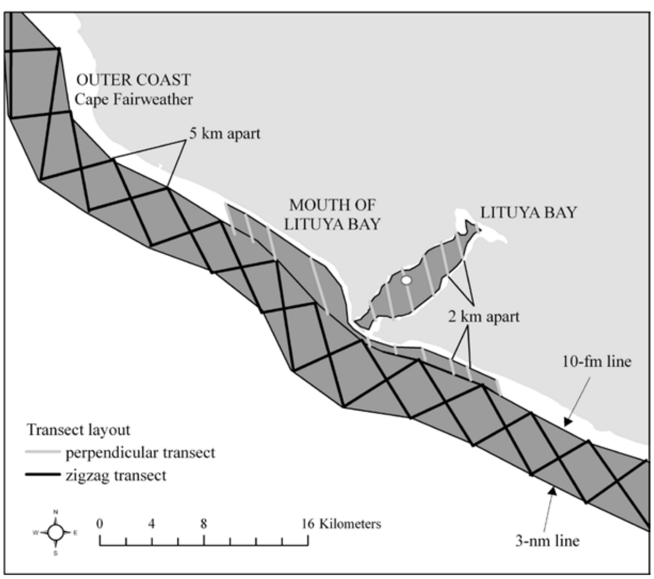

Fig. 2. Example of transect layout and delineation of survey area boundaries used to sample Kittlitz's Murrelet populations during the breeding season in southeastern Alaska, 2002–2009.

DISCUSSION

Our at-sea surveys demonstrated that Kittlitz's Murrelets in southeastern Alaska (outside of Glacier Bay) during the breeding season were geographically clustered and relatively uncommon, especially compared with the Marbled Murrelet (Figs. 3, 4). If we consider the most recent survey in each area and assume the surveys were independent, we estimate the Kittlitz's Murrelet population in southeastern Alaska, outside of Glacier Bay, to be 7906 (SE 2418) birds. We urge caution in interpreting this estimate, because we conducted our surveys over a 1 month period (17 June–21 July) and an 8 year timespan (2002–2009). Kittlitz's Murrelets can be highly mobile during a single season (M. Kissling, unpublished data). Furthermore, data from Kittlitz's Murrelets banded in Icy Bay showed that few birds returned to that area in subsequent years (M. Kissling, unpublished data). We emphasize the importance of conducting concurrent surveys for Kittlitz's Murrelet in multiple areas to calculate a regional population estimate.

We have too few data to estimate a trend of Kittlitz's Murrelet reliably. When estimating trend, sample size is hierarchically nested—observations of individual animals are nested within sample units (transects, in this study), which in turn are nested within years. Because degrees of freedom for the trend estimate pertain to the number of years, we have limited coverage and little power as yet to detect trends of Kittlitz's Murrelet in our study.

Given low statistical power, there is substantial risk of failing to detect a change in abundance when one exists. Kissling *et al.* (2007) performed simulations to estimate power to detect a decline in Kittlitz's Murrelet in Icy Bay and concluded ≥10 years of data were required because of the high spatial variation of this species. Nonetheless, in the areas where survey data were available for more than 1 year (Icy and Yakutat bays, Malaspina Forelands), it was striking how dramatically Kittlitz's Murrelet numbers varied among years. Marbled Murrelet abundance in the same areas and time period was comparatively stable (Figs. 5 & 6, Table 2). It is unclear whether this finding is biologically important, but it suggests the two species and the factors affecting their populations are less similar than is often assumed.

Although we conducted surveys over a number of years, the diversity of areas and habitats surveyed provided some insight into habitat selection by Kittlitz's Murrelets. First, Kittlitz's Murrelet abundance and density were consistently higher in sheltered bays and fjords (e.g. Icy, Yakutat, and Wilderness bays) than in the exposed waters of the Gulf of Alaska (e.g. Outer and Lost coasts, Malaspina Forelands; Table 2). In sheltered bays and fjords, tidal processes drive nutrient transport and prey aggregations, with submerged marine sills imparting small-scale variation in productivity (Hunt 1995). In contrast, the Alaska Coastal Current, the major coastal circulation feature of the Gulf of Alaska, which is largely driven by freshwater input, promotes localized nearshore upwelling that either enhances productivity or aggregates prey for *Brachyramphus* murrelets (Reed & Schumacher 1987, Neal *et al.* 2010). Kittlitz's Murrelet may be more abundant in protected bays and fjords because tidal-driven processes are more frequent and predictable than the localized upwelling events in exposed waters. In our study, the same pattern held for Marbled Murrelets, which feed on similar prey and likely benefit from similar conditions (Table 2, Fig. 4b; Day *et al.* 2003). Although Kittlitz's Murrelets were found in smaller numbers in exposed waters along the Outer and Lost coasts, in these locations they were found mainly adjacent to ice-dominated uplands (Fig. 3a).

Second, although our surveys and those of Agler *et al.* (1998) were not designed to test the relationship explicitly, it was clear that the at-sea distribution of Kittlitz's Murrelet in southeastern Alaska during the breeding season was strongly associated with glacially influenced marine waters (Fig. 4a), especially in comparison with the distribution of Marbled Murrelets (Fig. 4b). For example, using Kittlitz's and Marbled murrelet observations from the most recent survey in each area (Table 2) and those of Kendall & Agler (1998; Kittlitz's) and Agler *et al.* (1998; Marbled), we calculated the average linear distance to a glacier or icefield to be 7 km for Kittlitz's Murrelets

TABLE 2
Kittlitz's Murrelet (KIMU) and Marbled Murrelet (MAMU) peak abundance (number of birds) and density (birds/km²) by survey area and year, southeastern Alaska, 2002–2009[a]

Area or subarea	Survey date	Species count within 100 m of either side of boat			KIMU abundance (SE)	KIMU density (SE)	MAMU abundance (SE)	MAMU density (SE)
		KIMU	MAMU	UNMU				
LeConte Bay	8 July 2002	0	0	0	0	0	0	0
Thomas Bay	7 July 2002	0	358	0	0	0	4967 (3105)	84.6 (52.9)
Wilderness Bays	9–10 July 2002	27	482	0	555 (233)	2.34 (0.98)	9916 (2402)	41.8 (10.1)
Cross Sound	3–4 July 2003	2	844	18	28 (30)	0.05 (0.05)	16 027 (5841)	26.5 (9.7)
Outer Coast	7–13 July 2004	16[b]	1097[b]	90[b]	144 (59)	0.18 (0.07)	9896 (1601)	12.2 (2.0)
Outer Coast Bays	5 July 2003	0	28	2	0	0	408 (133)	12.6 (4.1)
Icy Point	10 July 2003	105	554	101	101 (33)	2.25 (0.74)	534 (137)	11.9 (3.1)
Mouth of Lituya Bay	14 July 2004	16	149	8	129 (60)	4.00 (1.86)	1206 (306)	37.3 (9.5)
Lituya Bay	6 July 2003	5	15	4	31 (22)	1.35 (0.96)	92 (41)	4.1 (1.8)
Yakutat Bay	16–19 June 2000[c]	20	249	321	966 (183)	0.85 (0.16)	12 025 (2282)	10.6 (2.0)
	17–22 June 2009	96	381	102	4414 (965)	3.90 (0.85)	12 902 (1912)	11.4 (1.7)
Manby Point	14 July 2002	52[b]	251[b]	33[b]	988 (437)	5.78 (2.56)	4767 (1631)	27.9 (9.5)
Malaspina Forelands[d]	26 July 1992[e]	384	345	265	641 (13)	39.23 (0.81)	386 (13)	23.7 (0.8)
	13 July 2002	9	355	16	10 (3)	0.59 (0.19)	378 (3)	23.2 (0.2)
	20 July 2008	16	184	43	39 (22)	2.38 (1.34)	343 (133)	21.0 (8.2)
	16 July 2009	101	217	55	165 (104)	10.13 (6.35)	373 (218)	22.8 (13.4)
Icy Bay	11 July 2002	237	11	23	2660 (99)	27.63 (1.03)	123 (32)	1.28 (0.38)
	9 July 2005	116	0	17	1317 (294)	10.31 (2.30)	0[f]	0
	23 July 2007	103	0	0	1000 (159)	8.47 (1.35)	0[g]	0
	14 July 2008	157	11	25	1949 (286)	16.52 (2.43)	137 (44)	1.16 (0.38)
	17 July 2009	68	11	4	705 (216)	5.23 (1.60)	114 (47)	0.85 (0.35)
Lost Coast	21 July 2008	20[1]	132[b]	58[b]	646 (259)	1.47 (0.59)	4266 (955)	9.7 (2.2)

[a] Unidentified murrelets (UNMU) incorporated into abundance, density estimates and standard errors (SE) for both species.
[b] Number of murrelets within 150 m of either side of boat.
[c] Surveys by Stephensen & Andres (2001).
[d] Variance calculated from detection probability and ratio of unidentified murrelets; no spatial variance included because single transect surveyed.
[e] Surveys by Kozie (1993).
[f] Peak abundance (SE) of Marbled Murrelets on 29 July 2005 was 14 (1) birds.
[g] Peak abundance (SE) of Marbled Murrelets on 4 July 2007 was 18 (1) birds.

and 37 km for Marbled Murrelets. Nevertheless, the average July sea surface temperature (2006–2008; following McClain *et al.* 1985) was 7.56 °C for Kittlitz's and 7.45 °C for Marbled murrelets (ESRI Inc., ArcMap, v9.3, Redlands, California). These simple summary statistics emphasize the importance of glaciers and icefields to Kittlitz's relative to Marbled murrelets and indicate that, at least at a broad scale, sea surface temperature does little to explain the apparent close association between Kittlitz's Murrelet and glaciers, as found by Day *et al.* (2003) at a finer scale.

Finally, the absence of Kittlitz's Murrelet in LeConte Bay is evidence of a possible change in the range of this species in southeastern Alaska, although absence is difficult to confirm and was well beyond the scope of our study. Historical accounts from the 1940s indicate the species was "common" in LeConte Bay (Webster 1950, Gabrielson & Lincoln 1959), with "10–20 Kittlitz's Murrelets each day" reportedly seen during 18–20 June 1946 (J.D. Webster, in litt.). In addition, at least five museum specimens collected in August 1944 (n = 2; US National Museum of Natural

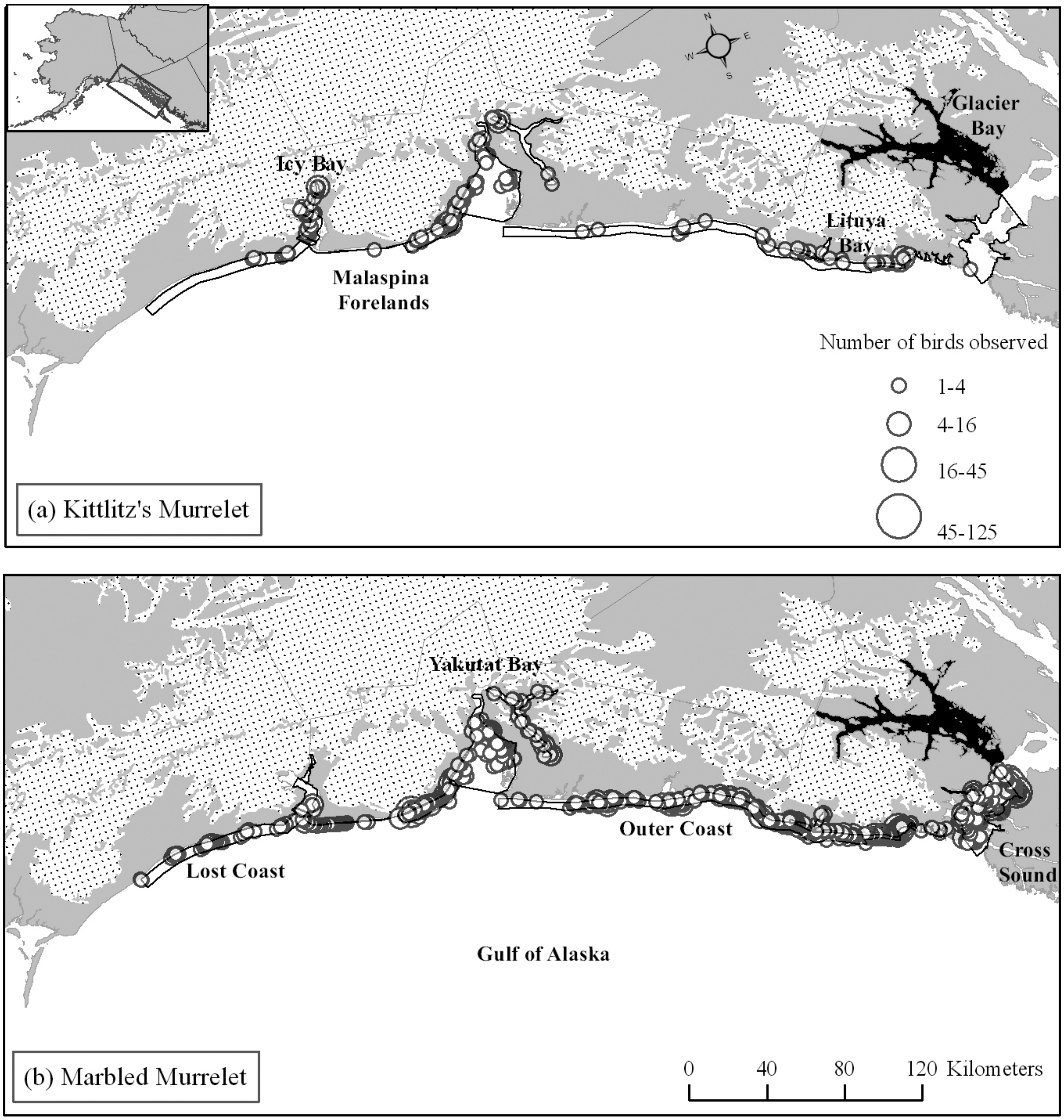

Fig. 3. Distribution and abundance of (a) Kittlitz's and (b) Marbled murrelets (identified birds only) in southeastern Alaska, based on the most recent survey in each area (except Glacier Bay, in black), 2002–2009. Glacier and icefields denoted by gray stippling; scale and symbol definitions apply to both panels.

History) and in June 1946 (n = 3; California Academy of Sciences) are from this area (R.H. Day, unpublished data). The last verified observation of a Kittlitz's Murrelet in LeConte Bay occurred in July 1994 (Kendall & Agler 1998; Fig. 4a), although we are aware of two searches for the Kittlitz's Murrelet in LeConte Bay since then. On 8 August 2001, no Kittlitz's Murrelets but numerous Marbled Murrelets were observed at the entrance to the bay (M. Kissling, unpublished data); similarly, on 10 July 2007, one unidentified *Brachyramphus* murrelet and "hundreds" of Marbled Murrelets were observed (M. Cady, US Forest Service, Wrangell, Alaska, pers. comm.). We are aware of occasional sightings of Kittlitz's Murrelets in the 1980s in Thomas Bay, about 50 km north of LeConte Bay (J. Hughes, Alaska Department of Fish and Game; W. Lehnhausen, Lindblad Expeditions & P. Walsh, US Forest Service, in litt.), but none more recent, despite survey effort in this study and by Lindell (2005) in July 1995 and August 1997. Therefore, we now consider the southern limit of Kittlitz's Murrelet (i.e. where birds occur consistently and have been observed holding fish) to be Holkam Bay and Tracy and Endicott arms ("Wilderness Bays" in this study; Fig. 4a).

Management implications

Given the apparently strong association with glacial habitats in southeastern Alaska, it is tempting to speculate on the role of icefields and glacier dynamics in the future of Kittlitz's Murrelet, even in the absence of a complete understanding of the relationship. If we assume that the fate of Kittlitz's Murrelet in southeastern Alaska is tied to glacial habitats, we believe that Kittlitz's Murrelet populations are likely to decline. Southeastern Alaska contains the largest system of temperate icefields and glaciers in North America, including half (24 of 51) of Alaska's tidewater glaciers (Molnia 2008). Most of the tidewater glaciers are retreating (Molnia 2008), and are experiencing high levels of ice thinning and loss

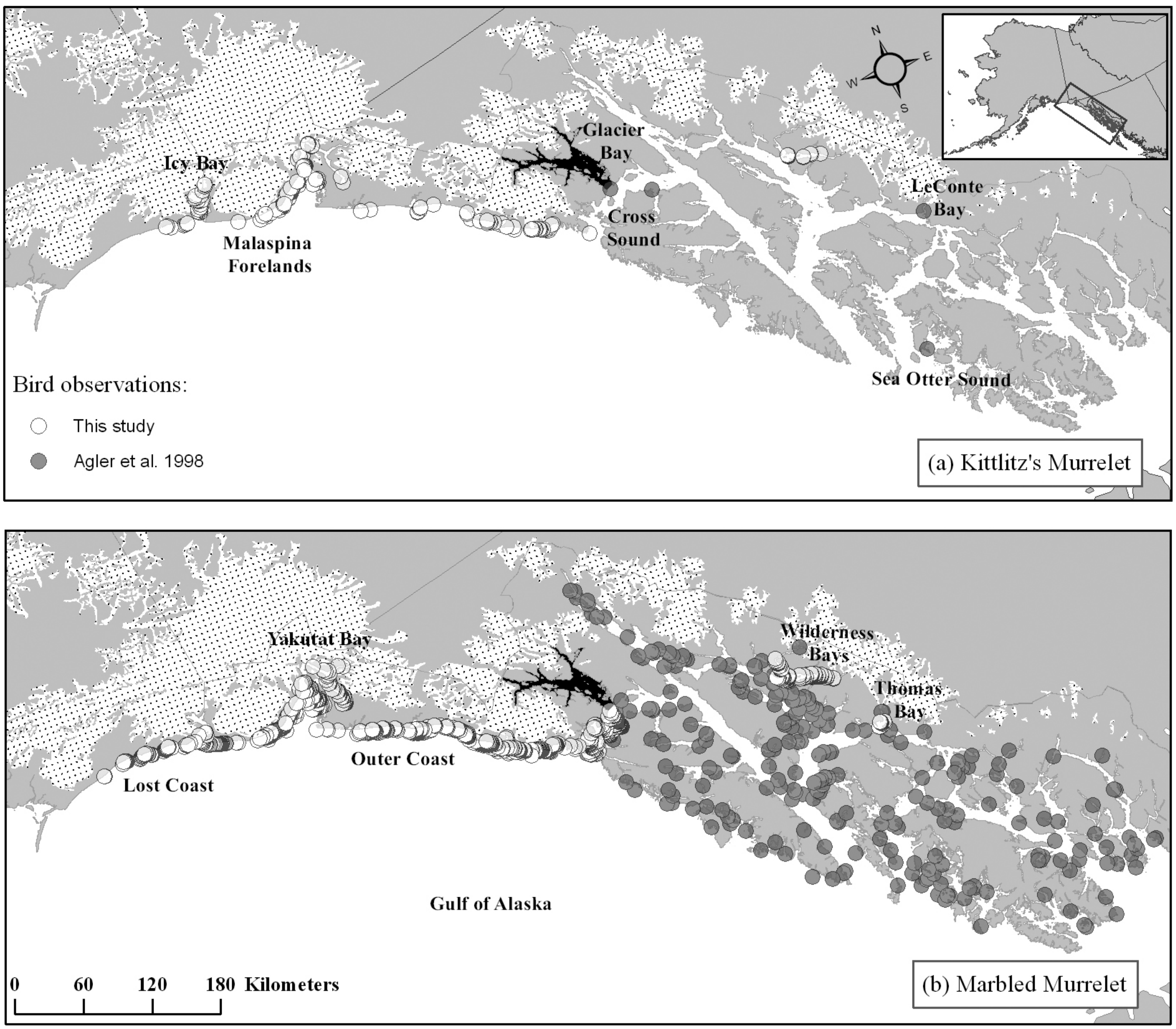

Fig. 4. Distribution of (a) Kittlitz's and (b) Marbled murrelets (identified birds only, unadjusted for group size) in southeastern Alaska based on the most recent survey in each during this study (2002–2009) and that of Agler *et al.* (1998) in 1996. Combined, these two surveys provided complete coverage of marine waters in southeastern Alaska, with the exception of Glacier Bay (black fill). Glacier and icefields denoted by gray stippling; scale and symbol definitions apply to both panels.

in the region (Larsen *et al.* 2007). Because of their low elevation, tidewater glaciers are thought to be particularly sensitive to changes in temperature (Larsen *et al.* 2007), thereby intricately linking the dynamics of glaciers to climate change.

In the absence of a reversal of ice loss, management of Kittlitz's Murrelet will need to focus on tractable sources of mortality and increased protection of the uplands and marine habitat important to murrelets. The latter includes particularly waters adjacent to ice-dominated uplands. These management and conservation actions should be guided by a concerted research effort, but some actions can be taken immediately. For example, we recommend increased conservation measures in and between Icy and Yakutat bays, especially near Manby Point, to minimize disturbance and unintentional take of Kittlitz's Murrelets. Potential anthropogenic impacts in this area include commercial and sport fishing, tourism and logging.

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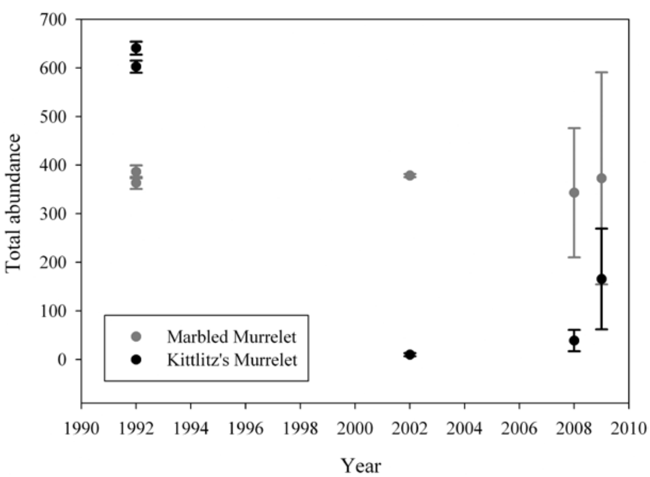

Fig. 5. Population estimates (and error bars) of Kittlitz's and Marbled murrelets along the Malaspina Forelands, 1992–2009.

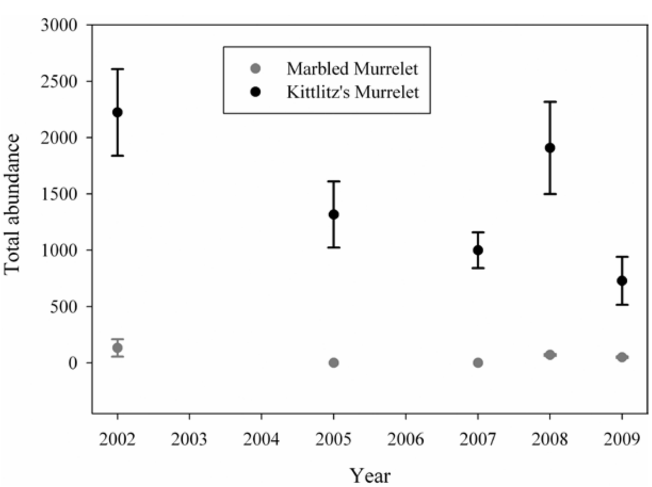

Fig. 6. Population estimates (and error bars) of Kittlitz's and Marbled murrelets in Icy Bay, 2002–2009.

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